Probing the Nuclei of Active Galaxies
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- Investigating B fields in AGN jets, especially the hypothesis that many (all?) AGN jets have helical B fields (note that then jets carry current!)
- Using Faraday effects to derive information about jet B fields and surrounding environment
- Studies of very rapid variability of compact AGN – scintillation vs. intrinsic variations
- Systematic studies of jets on wide range of scales
- Coordinated radio and optical polarization observations
Jets emerging from the centres of **Active Galactic Nuclei** on scales of 1000's of light years (kiloparsecs) – ultimate origin of activity is a **supermassive black hole** at the galactic centre.
Parsec-scale jets are one-sided, due to Doppler beaming of the radio emission in the direction of motion – the approaching jet is believed to be oriented close to the line of sight.

The jets show apparent “superluminal” motions – also a geometrical effect due to the fact that the relativistic jet is moving toward the Earth at a small angle to the line of sight.
• Observed radio emission is **synchrotron radiation** emitted by relativistic electrons moving through regions with magnetic (B) fields

• Synchrotron radiation is highly linearly polarised (up to about 75%)

→ *Degree* of linear polarisation carries information about degree of order of B field

→ *Plane* of linear polarisation carries information about orientation of B field (the two are orthogonal when the emitting plasma is “optically thin”)
Observed polarisation angles can be affected by Faraday rotation – plane of polarisation rotates when the EM wave travels through a region with magnetised plasma – RCP and LCP components obtain different velocities
Rotation is proportional to square of observing wavelength, and also depends on integral of electron density and line-of-sight component of magnetic field from source to observer:

\[
\text{Observed pol. angle} - \text{Intrinsic pol. angle} \propto \lambda^2 \int n \mathbf{B} \cdot d\mathbf{l}
\]

Coefficient of \( \lambda^2 \) is called the “rotation measure (RM)”. 
Arrays of radio telescopes used for Very Long Baseline Interferometry to achieve high angular resolution – study jets on parsec (light-year) scales.
Powerful diagnostic for presence of toroidal/helical B fields: Faraday-rotation gradient across the jet – due to systematically changing line-of-sight component of B field across the jet. If jet is viewed at ~90° to jet axis in source frame:
Croke, Gabuzda & Katz (in prep): RM gradient with same sense detected using 3.6+6+13+18cm VLBA data

Gabuzda, Murray, Cronin 2004:
Found expected behaviour for toroidal/helical B field viewed at 90° to jet axis in source frame in Mrk501

4th year project student in 2003
2nd year Summer student in 2004
New transverse RM gradients in several sources ...
Other signs of helical B fields - Extended regions of transverse jet B field (aligned E vectors)

2cm VLBA map of 1749+701; Gabuzda, Lisakov & Pushkarev, in prep.

18cm VLBA map of 1803+784; Gabuzda & Chernetskii 2003
“Sheath-like” jet pol structures – maybe interaction with surrounding medium, but more natural explanation is helical B field:

Pushkarev et al. 2005

Attridge, Roberts & Wardle 1999
If polarization “sheaths” are associated with helical B fields, some sources with “sheaths” should display RM gradients as well … and they do!

Gabuzda, Murray & Cronin 2004

Mrk501

Pushkarev et al. 2005
0300+470
(Askea O'Dowd's Master's thesis)
Possible 4\textsuperscript{th} year projects

- Deriving information about the properties of individual components/regions in the nearby bright radio galaxy 3C111 as they rapidly evolve and move outward from the centre of activity.

- Model fitting VLBI data for the TeV AGN Mrk501 obtained at 4 epochs separated by only 3-4 weeks, to look for evidence of extremely rapid motions and polarization changes in the jet.

- Deriving information about the pitch angles of helical jet B fields and the angles of the jets to the line of sight by calculating transverse Faraday-rotation profiles for a range of simple helical-field models, and comparing these to some of the observed profiles.

- If something else in this talk has grabbed you, let me know!
Radio Astronomy Group at UCC:

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Imaging a Non-Relativistic Jet